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TRANSLATIONS FROM OKEANOLOGIYA

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Corals and Sea Pens, Indicators of the Hydrological Profile

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The problem of studying the profile of a water body is one of the leading problems in marine hydrology. The method of studying the water profile by the biological characteristics occupies not the least important place in the solution of this problem. As indicators of the various water masses, various species or subspecies of animals can be used, but the exact classification of them can be made usually only by specialists. It is much more convenient to use groups of animals as indicators, all or the majority of representatives of which are associated with only certain water masses. Under conditions of the Arctic and Subarctic corals and sea pens, that is, representatives of the subclass Octocorallia and the two orders of Madreporaria and Antipatharia of the subclass Hexacorallia and class Anthozoa, can be such indicators. In the Atlantic, to the north of 40° north latitude and in the Arctic a few score species of Octocorallia, Madreporaria and Antipatharia are known, living chiefly in the bathyal and abyssal. In the shoals of the Arctic Seas only representatives of the genus Eunephthya s.l. (alcyonaria) can be encountered in this group. Three species of Octocorallia live exclusively in the cold abysmal waters of the Polar Basin and Scandinavian deep: these are the single northern representative of the order Xeniidea, Ceratocaulon wandeli (29), which reaches a tremendous size (almost three meters), the sea pen Umbellula encrinus f. encrinus (14, 15, 16) and the gorgon coral, noted by H. Broch as Acanella arbuscula (14), but which, in our opinion, is a new species which has not yet been described. Representatives of three genera: Eunephthya s.l. from the alcyonarids, Clavularia of the group of Stolonifera and Virgularia of the sea pens, can be encountered both in the abysmal Arctic and in the Atlantic waters. All the other corals and sea pens live only in Atlantic waters.

The general schema of water circulation in the North Atlantic and the portion of the Arctic Sea next to the Atlantic Ocean may be represented in the following way (2, 22, 25, 42, 43). Along the shores of North America a powerful warm current, the Gulf Stream, moves to the northeast. Passing through the southernmost part of the Grand Banks of Newfoundland, the Gulf Stream begins to "spread out" into separate streams, the main one of which--the North Atlantic current--crosses the ocean and goes to the area of the Faroe Islands. One part of this current goes to the Norwegian Sea and then to the North in several branches, penetrating into the Barents and

Greenland Seas. Another part of it, the Irminger current, running into the Faroe-Iceland baffle and the cold-water wall of the East Iceland current, turns to the West, washes the shores of Iceland and goes to Greenland. Mixing with the Arctic waters of the East Greenland Current, the waters of the Irminger current skirt Farewell Cape and form the West Greenland current, which moves to the North. The main part of the waters of the Current (about 75 percent) turns to the West at the Greenland-Canadian baffle and mixes with the Canadian cold Current. The current formed has the name of the Labrador Current; it moves to the South in two streams.

The coastal stream extends along the tectonic fracture parallel to the Eastern shores of Labrador and Newfoundland, and then partly turns to the West and goes into the Gulf of St. Lawrence (44), partly washes the slopes of Green and St. Pierre banks and mixes with Atlantic waters. The main stream moves along the outer margin of the shelf. In its cold center the temperature is 1.6-0°; the salt content, 32.5-34.0 grams per thousand. With increase in the depth the temperature and salt content increase to 2-3.5° and 34.5-34.8 grams per thousand (12, 13, 23).

The main stream separates off a quite large Flemish Cape branch, which passes over the northern slope of Flemish Cape bank and forms a complex system of eddy currents on the bank (1,23).

The main part of the water of the main stream passes along the eastern slope of the Grand Banks of Newfoundland and cuts into the flank of the Gulf Stream. The water of the main stream mixes partly with the Atlantic and partly submerges to great depths.

The currents--North Atlantic, Irminger, West Greenland and Labrador--make up a large cyclonic circulation with two halistases--Labrador and Irminger. The circulation is occupied by subarctic waters--the product of the regional transformation of the Gulf Stream waters. In both halistases surface water drops actively to depths of more than 1.5-2. kilometers and abysmal and bottom waters of the North Atlantic are formed at a temperature of 2.2-3.5° and with a salt content of 34.88-34.97 grams per thousand (5, 42).

The Cabot current carries warm and freshened coastal waters, extending along the continental shelf of Nova Scotia, out of the Gulf of St. Lawrence. When the coastal waters mix with the waters of the Gulf Stream, a special water mass is formed, the water of the continental terrace, which occupies the entire space between the coastal shoals and the main stream of the Gulf Stream and moves to the East in parallel with the Gulf Stream (37). Mixing with the Labrador waters, the waters of the terrace form the so-called abysmal coastal waters with a temperature of 4-7° and a salt content of 34.5-34.8 grams per thousand, which go through the Laurentian

Channel into the Gulf of St. Lawrence (26, 36). In recent years, it has been noted repeatedly (1, 3) that warm water penetrates from the southwest into the shoals of the Grand Banks of Newfoundland, where they, mixing with the Labrador waters, form local bank waters. In cold years the Labrador waters occupy all the shoals of the bank.

What that is new can an analysis of the distribution of corals and sea pens give to this picture?

In 1954-1960, collections of the bottom fauna in the Northwestern Atlantic (7) were made by expeditions of the Polar Scientific Research and Planning and Designing Institute of Marine Fishing and Oceanography imeni N. M. Knipovich (PINRO) on the research ships "Sevastopol'," "Odessa," and "Novorossiysk." In analyzing this material we found the following species of corals and sea pens (Table 1). The Table does not include the eurythermic species of sea pen, Virgularia mirabilis. The distribution of the forms which we found is shown in Figs 1 and 2.

An analysis of the Table and Figs 1 and 2 shows that the corals and sea pens which we found are distributed only along the continental terrace and are practically not found at depths of less than 200 or more than 3,000 meters. With what is this adaptation to the bathyal [deep water] associated? The continental shelves of the Arctic and Subarctic are occupied, as a rule, by relatively cold and freshened waters. At the same time, the upper bathyal of the North Atlantic and Atlantic portion of the Arctic Ocean is washed by waters with a temperature of no less than 2-3° and a salt content of higher than 30 grams per thousand. Naturally, in going from the tropics to the pole, the shallow-water species of corals and sea pens drop out of the group of fauna, and even in the temperate latitudes only bathyal warm-water species are maintained. Being adapted to specific conditions of the bathyal, primarily to a relatively slow movement of water, they do not go into the shallow water even under favorable temperature and salt content conditions. Thus, in the Mediterranean Sea the appearance of Kophobelemnon stelliferum and Funiculina quadrangularis are a sign of transition from the sublittoral to the bathyal (35). A rise of the bathyal forms to depths of less than 200 meters is possible only in places where an intermediate warm layer goes out into the shoals of the Atlantic waters, that is, in those places where the existential conditions approach those of the bathyal at these depths.

In the Northwestern Atlantic sea pens go out to depths of 130-150 meters only occasionally, in the region of Nova Scotia. The finding of Pennatula aculeata at a depth of 130-132 meters between Sambro [?] and Emerald banks can serve as an indication of penetration of Atlantic waters into the valley of the Scotian shelf and their rise to relatively

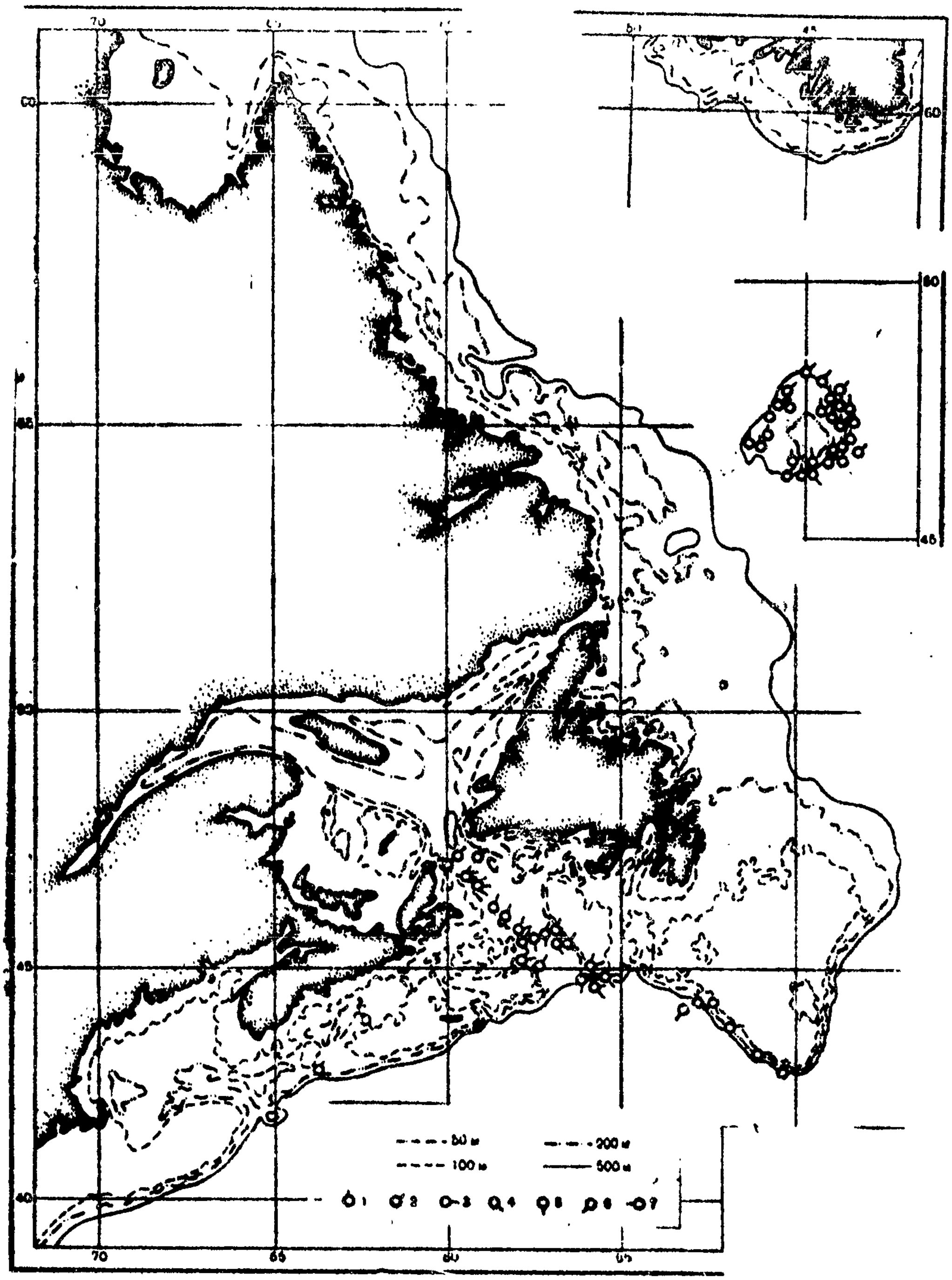

Fig 1. Distribution of Pennatulacea in the Newfoundland-Labrador Region According to the Data of the Research Ships of PINRO; 1. Pavonaria finmarchica; 2. Anthoptilum grandiflorum; 3. Pennatula grandis; 4. P. aculeata; 5. Kophobelemnon stelliferum; 6. Pennatula prolifera; 7. Funiculina quadrangularis.

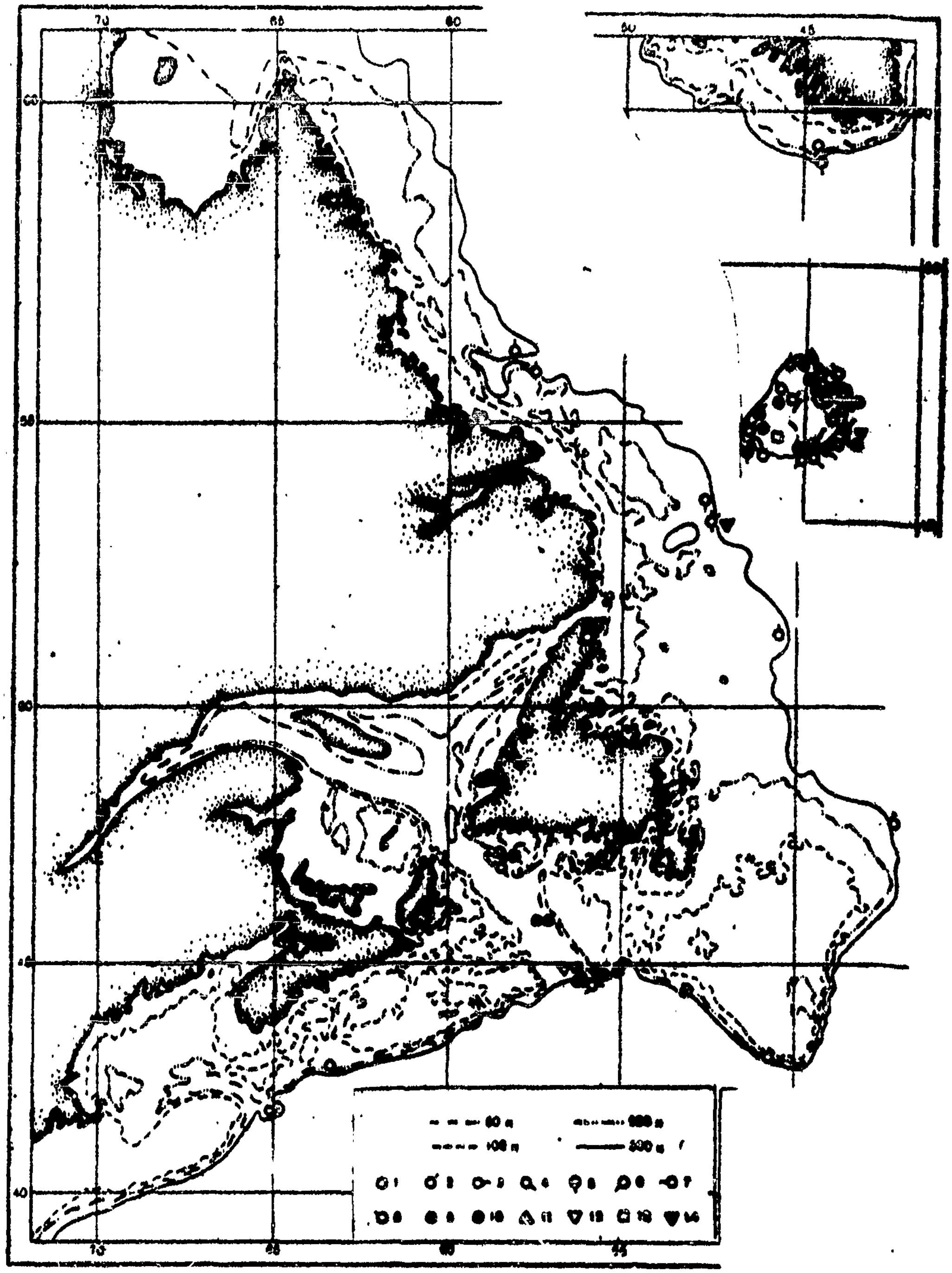

Fig 2. Distribution of Telestacea, Alcyonacea, Gorgonacea, Madreporaria and Antipatharia in the Newfoundland-Labrador Region According to the Data of the Research Ships of PINRO; 1. Paragorgia arborea; 2. Anthathela grandiflorum; 3. Acanthogorgia armata; 4. Paramuricea placomus; 5. Primnoa resedae-

/Continued on next page/

[Continued from previous page] formis; 6. Radicipes gracilis; 7. Apanella arbuscula; 8. Ceratoisisornata; 9. Bathypathes arctica; 10. Flabellum alabastrum; 11. Telestula septentrionalis; 12. Anthomastus grandiflorus; 13. Lophelia pertusa; 14. Trachymuricea kükenthali.

shallow depths; this is the result of the low power of the upper freshened layer of coastal waters at Nova Scotia (39).

Very many sea pens are found in the Laurentian Channel the under-water valley of Cabot Strait. Large Anthoptilum grandiflorum and Pennatula grandis, which reach 60-70 centimeters in height and which are caught in commercial trawls in quantities of several hundred per hour of trawling are the most characteristic components of the benthic biocoenosis of the Channel. They are encountered only in warm abysmal waters, deeper than 200-250 meters. Their strict adaptation to these waters confirms the idea (36) that the abysmal waters of the Laurentian Channel and Cabot Strait are an independent type of water. The abundance of sea pens in the Laurentian Channel is the result not only of favorable temperature and salt conditions but also of the favorable nature of the bottom: the sea pens, which dig into the bottom with the lower end of the base and not growing onto anything, naturally prefer soft bottoms. The bottom of the Laurentian Channel is covered with ooze and clayey ooze, whereas on the continental shelf at the same depth (250-500 meters) there is usually oozey sand, and less often, sandy ooze. The reason for the unusually high ooze content of the bottom deposits of the trough is the presence of a baffle, of an end moraine, which separates the bottom of the underwater valley of Cabot Strait dug out by a glacier from the continental terrace. Relatively low (it extends a few score meters above the bottom of the Laurentian Channel), this moraine markedly changes the conditions of the water circulation, being responsible for the slow movement of water in the bottom layers of the Laurentian Channel. The great ooze content of the bottom prevents the development of corals in the Laurentian Channel, since they attach to stones. Only Flabellum alabastrum, which lies freely on the surface of the bottom, is quite common.

Corals and sea pens are abundantly represented on the southern slope of St. Pierre Bank. They are not rare, although they are relatively few on the southwestern slope of the Grand Newfoundland Bank. This permits us to consider that the southern slope of St. Pierre Bank and the southwestern slope of the Grand Bank are under the influence of Atlantic waters. These waters are intermediate in their temperature and salt characteristics between the waters of the terrace and the Labrador waters and represent the product of their mixing. It must be supposed that the penetration of

Table

List of Octocorallia (with the Exception of Clavularia and Eunephthya), Madreporaria and Antipatharia, Found in Northwest Atlantic by Expeditions of PINRO in 1954-1960.

Вид	На каких глубинах встречен, м	Распространение	Глубина обитания, м (по литературным данным)
Класс Anthozoa, подкласс Octocorallia			
Отряд Telestacea			
Telestula septentrionalis Madsen	495—535	Северная Атлантика	740—2446
Отряд Alcyonacea			
Anthomastus grandiflorus Verrill	248—630	От Тронхейма до Канарских о-вов и от Ньюфаундленда до о-ва Гренады; Девисов прол., юг Исландии	140—2875
Отряд Gorgonacea			
Paragorgia arborea (L.)	295—520	От юго-западной части Баренцева моря до Португалии, от Лабрадора до Новой Англии, Исландия, Южная Атлантика, Сев. Пацифика	72—800
Anthothela grandiflora (M. Sars)	260—335	От Финмаркена до о-вов Зеленого мыса, от Ньюфаундленда до м. Код, Вест-Индия ?	(75) 130—1700
Acanthogorgia armata Verrill	315—700	От Португалии до Марокко, от Ньюфаундленда до м. Код, Исландия	275—1267
Paramuricea placomus (L.)	180—400	От Лофотен до о-вов Зеленого мыса, Ньюфаундленд, Новая Англия, Исландия	(75) 150—1800
Trachymuricea kükenthali (Broch)	400—480	От Лофотен до Скагеррака, Исландия, Фарерские о-ва	150—1200
Primnoa resedaeformis (Gunnerus)	185—445	От западного Мурмана до Португалии, от Девисова прол. до залива Мэн, Северная Пацифика, Охотское и Японское моря	95—1000
Radicipes gracilis (Verrill)	340—700	От Девисова прол. до Новой Англии, Исландии	957—3173
Acanella arbuscula (Johnson)	315—750	От Исландии до Канарских о-вов, от Девисова прол. до Новой Англии	192—3173
Ceratoisis ornata Verrill	200—515	От Ньюфаундленда до о-ва Гренады, возможно от Ирландии до о-вов Зеленого мыса	275—1540
Отряд Pennatulacea			
Kophobelemnon stelliferum (O. F. Müller)	240—840	Северная Атлантика (на север до Лофотен и Девисова прол.), Индийский океан, Япония	40—4400
Funiculina quadrangularis (Pallas)	315—850	От Тронхейма до Средиземного моря, от Ньюфаундленда до Юкатана, Индийский океан, Япония	18—2870
Pavonaria finmarchica (M. Sars)	245—495	От западного Мурмана до Северного моря, от Ньюфаундленда до м. Код, Японское и Охотское море	40—1780
Anthoptilum grandiflorum (Verrill)	177—730	От Девисова прол. до Буэнос-Айреса и м. Доброй Надежды	100—3185
Pennatula grandis [illegible]	250—700	От Лофотен до Скагеррака, от Ньюфаундленда до Бермудских о-вов	60—2200
P. aculeata Kor. et Dan.	(130—132) 277—700	От Лофотен до Азорских о-вов, от Девисова прол. до зал. Чезапик, Индийский океан	20—2200
P. ?bellifera Jungersen juv.	2150	Девисов прол. (по мнению Ф. А. Пастернака [8] одна из форм P. phosphorea L., распространенной в Атлантическом, Тихом и [illegible] глубинах 20—3182 м)	2200—2700

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1 Вид	2 На каких глубинах встречен, м	3 Распространение	Глубина обитания, м (по литературным данным) 4
		Подкласс Hexacorallia	
		Отряд Madreporaria	
Flabellum alabastrum Moseley	218—830	От Денисова прол. до экватора, от Ирландии до Канарских о-вов	357—2055
Lophelia pertusa (L.)	290—275	Атлантический (на север до Ньюфаундленда, Исландии и Финмаркена) и Индийский океаны	60—2100
		Отряд Antipatharia	
Bathypathes arctica Lütken	330—313	Денисов прол., Фарерские о-ва	1100—1200

1. Species; 2. Depth at Which Encountered, Meters; 3. Distribution; 4. Lives at a Depth of, Meters (According to Data in the Literature); 5. Class Anthozoa, Subclass Octocorallia; 6. Order Telestacea; 7. North Atlantic; 8. Order Alcyonacea; 9. From Trondheim to the Canary Islands and from Newfoundland to the Island of Grenada; Davis's Strait, South Iceland; 10. Order Gorgonacea; 11. From the Southwestern Part of the Barents Sea to Portugal, from Labrador to New England, Iceland, the South Atlantic, and North Pacific; 12. From Finmarken to the Cape Verde Islands, from Newfoundland to Cape Cod, West Indies?; 13. From Portugal to Morocco; from Newfoundland to Cape Cod, Iceland; 14. From Lofoten to the Cape Verde Islands, Newfoundland, New England and Iceland; 15. From Lofoten to Skagerrak, Iceland, and the Faroe Islands; 16. From Western Murmansk to Portugal, from Davis's Strait to the Gulf of Maine, North Pacific, Sea of Okhotsk and Sea of Japan; 17. From Davis's Strait to New England, Iceland; 18. From Iceland to the Canary Islands, from Davis's Strait to New England; 19. From Newfoundland to the Island of Granada, Possibly from Ireland to the Cape Verde Islands; 20. Order Pennatulacea; 21. North Atlantic (to the North of Lofoten and Davis's Strait), Indian Ocean and Japan; 22. From Trondheim to the Mediterranian Sea, from Newfoundland to Yucatan, the Indian Ocean and Japan; 23. From Western Murmansk to the North Sea, from Newfoundland to Cape Cod, the Sea of Japan and the Sea of Okhotsk; 24. From Davis's Strait to Buenos Aires and the Cape of Good Hope; 25. From Lofoten to Skagerrak, from Newfoundland to the Bahama Islands; 26. From Lofoten to the Azores, from Davis's Strait to Chesapeake Bay, the Indian Ocean; 27. Davis's Strait

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/Table continued from previous page/ (In the Opinion of F. A. Pasternak (8), One of the Forms of P. phosphorea L., Widespread in the Atlantic, Pacific and Indian Oceans at Depths of 20-3,182 meters); 28. Subclass Hexacorallia; 29. Order Madreporaria; 30. From Davis's Strait to the Equator, from Ireland to the Canary Islands; 31. Atlantic (In the North as far as Newfoundland, Iceland and Finmarken) and the Indian Oceans; 32. Order Antipatharia; 33. Davis's Strait, Faroe Islands.

Atlantic waters into the shoals of the Grand Bank is a regular phenomenon in this area. The relative paucity of corals and sea pens in this area is possibly the result of the fact that the Labrador waters come here from time to time also.

There is an entirely different picture on the Eastern slope of the Grand Bank. Here, in the upper bathyal we did not find either corals or sea pens. They live here only at a depth of more than 500 meters, which we practically did not study because of the exceptional difficulty of trawling operations on the steep slope cut up by underwater canyons. The main stream of the Labrador current on the Eastern slope of the Grand Bank is squeezed between the Bank waters in the West and the Atlantic waters in the East. Along the Eastern margin of the Stream active water-mixing processes occur, and the mixed water drops actively to the bottom. Sponges, hydroids, bryozoans and polychetes, sabellids, that is animals which feed on particles suspended in the water and which develop only when there are bottom currents of adequate intensity, are very abundantly represented on the Eastern slope of the Bank and drop to depths of 300-400 meters. As far down as 300-400 and, in places 500 meters, such shallow-water animals as the cake urchin, Echinarachnius parma, and the bivalve mollusk, Cyrtodaria aliqua, are found. The sandy bottoms here are noted to a depth of 200-250 meters; oozey-sandy bottoms, to 700-800 meters (on the southwest slope of the Bank, to 100-150 and 200-250 meters, respectively). The low water temperature, usually 0-+2° and the hard bottoms do not permit the warm-water sea pens and corals to live here.
We found a multitude of corals and sea pens (15 species) on Flemish Cape Bank. It is separated from the Grand Bank of Newfoundland by a narrow (about 10 miles) underwater strait whose flat bottom lies at a depth of 1200 meters. Despite the narrowness of the strait, the fauna of Flemish Cape are very much different from the fauna of the adjacent area of Grand Bank. There are practically no cold-water animals here. A number of lower-arctic-boreal species with divided areas of distribution (northern part of the Pacific Ocean and Northwest Atlantic), such as the cake urchin, Echinarachnius parma, the crab Chionoecetes opilio, and a number of others,

are also absent from the Flemish Cape. At depths from 200 to 300-350 meters the hydroids and bryozoans are quite variously represented, although there are much fewer of them than on the Eastern slope of Grand Bank. This speaks for an increased rate of movement of the water in the bottom layers, although the speed of the current is far from reaching the level of that on the Eastern slope of Grand Bank. At this depth there is a predominance of boreal forms of animals; however, there are no sea pens even here and corals are encountered only occasionally. Finally, beginning with a depth of 330-340 meters an area of abundance of corals, sea pens and other warm-water animals encircling the Bank as a solid ring begins (Fig 3).

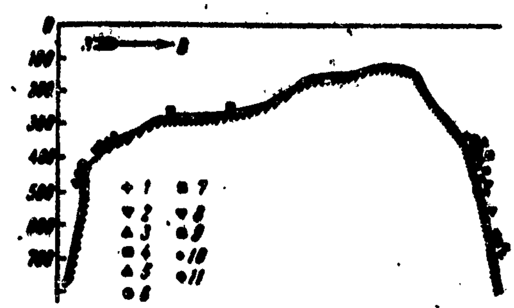

Fig 3. Longitudinal Section Through Flemish Cape Bank at 47° North Latitude (the Vertical Scale is Approximately 200 Times Greater Than the Horizontal) and the Bathymetric Distribution of Corals and Sea Pens on the Bank Between 46°40' and 47°20' North Latitutde: 1. Paragorgia arborea; 2. Anthothela grandiflora; 3. Paramuricea placomus; 4. Radicipes gracilis; 5. Acanella arbuscula; 6. Bathypathes arctica; 7. Flabellum alabastrum; 8. Anthomastus grandiflorus; 9. Lophelia pertusa; 10. Pavonaria finmarchica; 11. Antheptilum grandiflorum.

The shallowest water part of the Bank is washed by subarctic waters of the Flemish Cape branch; the bottom temperature at depths up to 200 meters is 2.6-3.6°; the salt content, 34.4-34.7 grams per thousand. In the area in which the corals and sea pens live the bottom temperature is 3.3-4.0°; the salt content, 34.8-34.9 grams per thousand. These are abyssal Labrador waters, apparently, with a certain admixture of the waters of the terrace coming to Flemish Cape

Bank from the South. At a depth of 200 to 300-350 meters the mixing area of these waters is found. It must be supposed that the localization of the three vertical hydrological and faunal zones in depth is associated, to some degree, with the topography of the bottom of the Bank. Characteristic of the geomorphology of the Flemish Cape Bank is the steepness of the southern and eastern slopes and the gently sloping nature of the northern and western slopes, where two terraces are readily noticeable, apparently submerged shorelines, at depths of about 150 and 270 meters. The lower terrace is bounded by low (5-10 meters) projections at depths of 250 and 300 meters which apparently encircle the entire Bank (4). It may be supposed that the age of these terraces is Pleistocene, because the terraces found by Holtedahl (27) at a depth of 270 meters along the shores of Norway, Scotland, Ireland and Iceland were considered by him and Rigg (41) to belong to the period of maximum glaciation and the terrace found at a depth of 150 meters in the region of the underwater Hudson Canyon (New England) is referred to the Wisconsin Glacial Period (24).

At a depth of less than 170 meters, on the upper terrace, the bottoms are sandy, the currents are quite active. On the western slope of the Bank, on the surface of the second terrace, there is a patch of sandy ooze (4) which coincides with the position of the region of warm currents (23). Along the margins of the second terrace the speed of the current is increased; the bottom is oozy sand with stones. Such a bottom occurs also in the area of development of the corals and sea pens. Evidently, the absence of corals and sea pens from the lower terrace is not determined by the conditions of the bottom and not by the difference in temperature and salt content which are not negligible factors for the animals, but specifically by the fact that lower than 300-350 meters there is a prevalence of abysmal Labrador waters mixed with waters of the slope. According to the biological characteristics this type of water is very much different not only from the subarctic water of the Flemish Cape branch but also from the waters of the mixing area at depths of 200 to 300-350 meters. It is curious that at depths of 200 to 300-350 meters there is a predominance of the "golden redfish" Sebastes marinus (Linne) and lower than that, of the "deep-water redfish" (Sebastes mentella Travn.) in the fish catches.

To the northwest of Flemish Cape Bank, on the continental shelf of Northern Newfoundland and Labrador we did not once encounter a sea pen, except for the eurythermic species, Virgularia mirabilis. No Antipatharia were found there either. However, four species of Gorgon corals, Paragorgia arborea, Primnoa recedaeformis, Anthothela grandiflora and Trachymuricea kükenthali--were still noted along the shores of Labrador. Here, they are encountered at a depth of no less

than 300 meters, usually at depths of [illegible] meters, and do not go into the deep underwater valleys of the continental shelf dug out by the glacier at all, there [illegible] thermophilic animals are encountered (the sea urchin, [illegible] fragilis, and others).

In the area where the corals live the abyssal Labrador waters have a bottom temperature of [illegible]-3.6° and a salt content of [illegible] grams per thousand, that is, almost the same characteristics as the waters of Flemish Cape Bank. Therefore, the abyssal waters of the Labrador Current have nothing in common with the waters of the cold center of the Labrador Current (negative temperature, salt content of less than 34 grams per thousand). These are modified Atlantic waters coming from the shores of Western Greenland. They move to the South, bordering the cold stream on the East, (these waters specifically enter the Flemish Cape shoals) and lying on the bottom. The abyssal Labrador waters go into the underwater valleys of the shelf, but judging by the absence of corals from these valleys, this occurs in very small quantities.

Why is the warm-water fauna so poor along the shores of Labrador? The temperature difference between the waters of Labrador and Flemish Cape Bank at depths of more than 300-350 meters is slight; the bottoms are the same, the degree of water mobility is also apparently the same. However, the most characteristic feature of the benthos in the upper bathyal near Labrador and Newfoundland, which distinguishes it markedly from the benthos of Flemish Cape Bank, is the combined existence of warm-water and cold-water species. Specifically, along with the warm water corals, Primnoa resedaeformis and Paragorgia arborea, there are such cold-water animals as the sea lily, Heliometra glacialis and the starfish, [illegible] furcifer. This phenomenon becomes understandable if we keep in mind the yearly and perennial variations in the intensity of the cold stream of the Labrador current (2). Increase in the power of the current of the Gulf Stream waters involves an increase in the degree to which cold waters are carried out of the Polar Basin and, therefore, an increase in the power of the current of cold Labrador waters. Reduction in the power of the current of Gulf Stream waters brings about a weakening of the cold stream of the Labrador Current. As the result, sections of the upper bathyal in the same areas through which the main stream of the Labrador Current passes are under the influence, now of warm, now of cold waters. Naturally, under such conditions only the quite eurythermic forms of warm-water animals can survive. Actually, all four species of Gorgonacea which we found along the shores of Labrador also live along the shores of Norway, going to the north of the Arctic Circle.

The waters of the cold center of the main stream do not go to the Flemish Cape Bank judging by the absence of cold-water species. Moreover, the absence of species with separated Pacific-Western-Atlantic areas of distribution from Flemish Cape indicates that such waters have not come into Flemish Cape for the last several thousand years. These animals penetrated into the Newfoundland area from the Pacific Ocean along the northern shores of Canada, apparently during the period of the post-glacial climatic optimum: 4000-6000 years ago. The hydrological conditions and the bottom of the shoal-water banks of Flemish Cape are favorable for them, but adult animals cannot get through the great depths of the strait which separates Flemish Cape from Grand Bank where they live. If the cold Labrador waters washing the shoals of Grand Bank came to Flemish Cape they would bring with them the larvae of these animals, and a differentiated population of Pacific-Western-Atlantic animals would be formed at Flemish Cape, which, as we see, did not occur. Generally speaking, the water profile in deep water depends to a tremendous degree on the topography of the bottom (26); therefore, it may be considered that the types of waters which we have analyzed, namely, the cold Labrador waters, the warm abyssal Labrador waters, the waters of the Flemish Cape branch, the waters of the southwestern slope of Grand Bank, the abyssal waters of the Laurentian Channel, are by no means temporary formations. Their hydrological characteristics could have and can still change to a certain degree, but their distribution and basic properties of these types of waters have not undergone essential changes since the ice of the last glaciation melted and since the modern water conditions were established in the North Atlantic.

North of the Greenland-Canadian underwater moraine there are no warm-water corals or sea pens; in the abyssal waters of Baffin Bay animals of the high arctic live, such as the sea pen Embellula encrinus f. encrinus.

Along the southwestern shores of Greenland, according to the data of I. N. Sidorenko (9) and his collections, which he gave us for classification, the Gorgonacea Paragorgia arborea and, less commonly, Paramuricea placomus and Primnoa recedaeformis live. This last species is also encountered near Farewell Cape at relatively low depths, about 200 meters. The corals also go into the underwater valleys of the shelf and into the abyssal sections of the Greenland fjords here (9, 38). Therefore, the Atlantic water current here is stronger than along the shores of Labrador. This is natural, for on route from Greenland to Labrador the temperature and volume of the Atlantic Ocean water carried by the current fall off considerably.

Corals and sea pens are very abundantly represented near the shores of Western Greenland in the lower bathyal,

at depths of 650–27 meters. Here, Telestula septentrionalis; Madsen Alcyonacea; Anthomastus grandiflorus Verrill, Gorgonacea; Paragorgia arborea (L.) (L.) Anthothela grandiflora (M. Sars); Acanthogorgia armata Verrill; Paramuricea placomus (L.); Trachymuricea kukenthali (Broch); Primnoa resedaeformis (Gunn.); Stenogorgia borealis Kramp; S. rosea Grieg; Radicipes challengeri (Wright & Studer); R. gracilis (Verrill); Acanella arbuscula (Johnson); Isidella lofotensis M. Sars; Ceratoisis ornata Verrill Pennatulacea; Pennatula aculeata Kor. & Dan.; P. grandis Ehrenb.; P. phosphorea L. P. aculeata Jungersen; Stylatula elegans Kor. & Dan. Pavonaria finmarchica M. Sars; Halipteris christii (Kor. & Dan.); Funiculina quadrangularis (Pall.); Protoptilum thomsoni Koll.; Distichoptilum gracile Verrill; Anthoptilum grandiflorum (Verrill); Kophobelemnon (Eukophobelemnon) stelliferum (O. F. Muller); Umbellula encrinus lindahli Koll.; Madreporaria; Flabellum alabastrum and other species (30, 33, 38). The abundance of warm-water animals at such depths is possibly connected with the fact that subarctic waters in the Labrador circulation drop to the bottom, causing an almost complete temperature uniformity at depths from 200 meters to the bottom in this area.

According to the material of the PINRO expeditions and data in the literature (14–21, 28–34, 38, 40, 45, 46 and others), we made out a map of the distribution of 36 warm-water and two cold-water species of corals and sea pens in the North Atlantic and adjacent part of the Arctic. (Fig 4).

On the map, the northern boundary of distribution of the warm-water species is readily seen; it coincides with the boundary of distribution of the cold-water forms (warm-water and cold-water species were not encountered a single time together). This boundary separates the Atlantic boreal and arctic areas. However, while in the regions of the Atlantic baffle and Norwegian Sea this boundary is defined very distinctly by the distribution of warm-water corals and sea pens, in the regions of Labrador, Newfoundland and Baffin Land in the West, and in the region of the Barents and Greenland Seas in the East, it is poorly outlined. For the Northwest Atlantic it has been noted above that the gradual impoverishment of the fauna in going along the course of the stream of Atlantic waters occurs gradually under the influence of local hydrological changes. The same is true for the Norwegian, Barents and Greenland Seas. Many species of corals and sea pens, such as Acanella arbuscula, Anthoptilum grandiflorum and Flabellum alabastrum are not encountered north of the Atlantic threshold. A whole series of species, namely, Anthomastus grandiflorus, Paramuricea placomus, Trachymuricea kükenthali, Isidella lofotensis, Pennatula grandis P. aculeata, and others are not noted

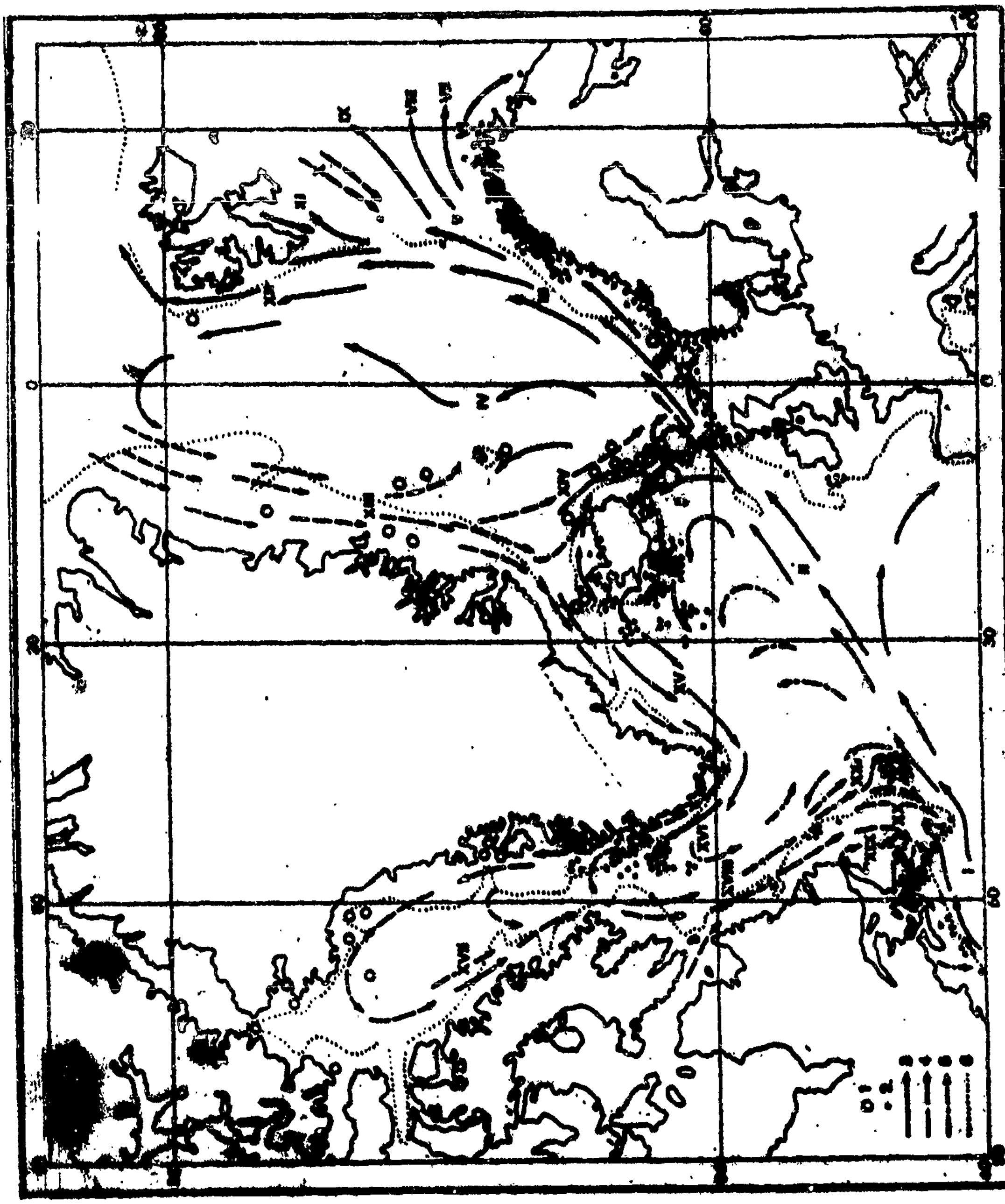

Fig 4. Distribution of Corals and Sea Pens--Indicators of the Water Masses in the Atlantic and Arctic: 1. Cold-Water Species; 2. Warm-Water Species; 3. Warm Currents; 4. Cold Currents; 5. Mixed Water Currents; 6. 500-Meter Isobath. The Roman Numerals Designate the Following Currents: I. Gulf Stream; II. North Atlantic Current; III. Eastern Branch of the Norway Current; IV. Western Branch of the Norway Current; V. North Cape Current; VI. Coastal Branch of the Murmansk Current; VII. The Main Branch of the Murmansk Current; VIII. Central Branch of the Murmansk Current; IX. Northern Branch of the North Cape Currents; X. Bear Current; XI.

[Continued on next page]

/Fig 4. Continued from previous page./ South Cape Current; XII. West Spitsbergen Current; XIII. East Greenland Current; XIV. East Iceland Current; XV. Irminger Current; XVI. West Greenland Current; XVII. Canadian Current; XVIII. Labrador Current; XIX. Coastal Stream of the Labrador Current; XX. Main Stream of the Labrador Current; XXI. Flemish Cape Branch; XXII. Cabot Current.

Cold-Water Species

Xeniidea; Ceratocaulon wandeli Jungersen, Pennatulacea; Umbellula encrinus f. encrinus (L.).

Warm-Water Species

Telestacea: Telestula septentrionalis; Madsen Alcyonacea; Anthomastus grandiflorus Verrill, Gorgonacea; Paragorgia arborea (L.) (L.) Anthothela grandiflora (M. Sars); Acanthogorgia armata Verrill; Paramuricea placomus (L.); Trachymuricea kukenthali (Broch); Primnoa resedaeformis (Gunn.); Stenogorgia borealis Kramp; S. rosea Grieg; Radicipes challengeri (Wright & Studer); R. gracilis (Verrill); Acanella arbuscula (Johnson); Isidella Lofotensis M. Sars; Ceratoisis ornata Verrill Pennatulacea; Pennatula aculeata Kor. & Dan.; P. grandis Ehrenb.; P. phospho res L. P. aculeata Jungersen; Stylatula elegans Kor. & Dan. Pavonaria finmarchica M. Sars; Halipteris christii (Kor. & Dan.); Funiculina quadrangularis (Pall.); Protoptilum thamsoni Koll.; Distichoptilum gracile Verrill; Antheptilum grandiflorum (Verrill); Kophobelemnon (Eukophobelemnon) stelliferum (O. F. Muller); Umbellula encrinus lindahli Koll.; Madreporaria; Flabellum alabastrum Moseley, F. macandrewi Gray, Stephanotrochus moseleyanus Sclater; Fungiacyathus fragilis M. Sars, Vaughanella sp.; Lophelia pertusa (L) Amphelia ramea (L.) Antipatharia; Bathypathes arctica (Lütken).

north of Western Norway (Trondheim and the Lofotens), that is, the places where the Norway current separates into separate branches. At Finmarken, where the North Cape current divides into the Murmansk current and the northern branch of the North Cape current, Lophelia pertusa, Amphelia ramea and others fall out. Occasional specimens of Funiculina quadrangularis, Pavonaria finmarchica, Primnoa recedaeformis, Paragorgia arborea (11) reach the main and coastal streams of the Murmansk current. On the Kola meridian (33°30' east longitude) we did not encounter any of these species. Only Paragorgia arborea is encountered on Kopytov Bank (73° north latitude, 15° east longitude). The boundary of the boreal area passes along the entrance to Kis Fjord at Spitsbergen (6) and to the west of Svyatoy Nos Cape in Eastern Murmansk (10) but there were no warm-water corals at West Spitsbergen or at Bear Island or at Eastern Murmansk.

There, however, there are other warm-water animals, but their number decreases in going to the East and North with gradual cooling of the Atlantic waters (6, 10). Therefore, the stepwise nature of the gradual impoverishment of the warm-water fauna is a characteristic feature of the zoogeography of the North Atlantic, and of more than just the Atlantic. Apparently, the marked impoverishment occurs in places where lateral branches separate from the warm Atlantic current or where this current divides into separate streams. In those areas where warm and cold waters are adjacent to one another (Atlantic threshold, Norwegian Sea), no gradual impoverishment of fauna is observed; the boreal antarctic fauna is separated here only by a narrow transitional strip with a mixed population.

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Caspian Fouling and its Changes in the Past Ten Years
(From 1951 Through 1961)

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Introduction

Appreciable changes in the plant and animal fouling in the Caspian Sea have occurred under the influence of 2 factors--changes in the hydrobiological conditions of the sea and the introduction of new organisms.

Referring to the first factor there are changes in the salinity, water temperature, oxygen profile, water contamination, destruction by fish, the presence of competition between organisms, etc.; frequently, such changes are not long lasting, for example, the change in the salinity in the North Caspian caused by floods of the Volga River last several months. In other cases, for example, with prolonged continuous contamination of the water in ports and harbors an impoverishment of the fauna and flora occurs in several years. An example of this is the Bakinskaya Bukhta /Baku Bay/. We shall not analyze here the changes in the animal and plant kingdoms which take place over centuries, associated with changes in the climate, the level and the geological history of the water body: the appearance, existence and disappearance of its connections with the Pont and Aral Sea (19).

The increase in the salt content and the unfavorable oxygen profile in the North Caspian in 1936-1937 considerably changed its benthos (3, 28). In subsequent years, in various regions of the sea, appreciable changes in the benthos also occurred associated with the change in the hydrobiological profile (4, 23).

The second factor, the introduction of new encrusting organisms, has been noted by many investigators. With the development of navigation in various seas progressively more introducents were found. Some of these organisms acclimatize themselves to new places, for example, the polychete Mercierella, the barnacle Elaminius modestus, the crabs Rhithriopanopeus harrisi and Eriocheir sinensis to the waters of Northwestern Europe, or the mollusk Rapana bezoar, to the Black Sea. Others, such as lepadids and some balanids are frequently carried into the cold waters and survive the first summer there, and sometimes even multiply at this time, but die in the winter (8, 14). Some warm-water encrusting fauna also survive the winter in the higher latitudes (however, only under distinctive conditions in the warm waters of electric power stations on the sea (30)).

In the Caspian the composition and number of encrusting fauna changed particularly considerably after the opening of the Volga-Don Canal, when many ship-fouling organisms were carried from the Black Sea and the Sea of Azov. The majority of the new introducents encountered no serious competitors, because many ecological niches had not been occupied. The existence of free niches in such a sea as the Caspian is readily explained by the history of this body of water, in which at the beginning of the century many marine organisms died out, and chiefly salt-water and fresh-water organisms were preserved. Mordukhay-Boltevskoy (19) notes that there are few true forms of epifauna among the autochthonous Caspian fauna.

In the 1930's, apparently on the feet of divers [birds], Rhizsolenia diatoms were transplanted to the Caspian Sea and multiplied there in tremendous numbers. Two species of mullets, two species of prawns, the polychete Nereis, and the mollusk Syndesmya, transplanted there by biologists, survived equally well (15, 16). However, all these organisms exert a comparatively slight influence on the fouling.

The first appreciable change in the fouling in the Caspian Sea occurred in the 1920's, when after the mollusk Mytilaster penetratedinto the Caspian Sea on the bottoms of cutters after rapid transfer of them by rail from the Black to the Caspian Sea. However, despite the fact that the Caspian fouling had not been studied before the introduction of Mytilaster it may be supposed that after the appearance of this introducent the fouling changed only qualitatively. In the Middle and Southern Caspian Mytilaster displaced Dreissena and occupied its place. Being similar to Dreissena in its size, mode of attachment, feeding and possibly growth rate, Mytilaster formed approximately the same kind of colonies as Dreissena creates in the North Caspian and which, it must be supposed, were in existence in the Middle and South Caspian before the introduction of Mytilaster.

Only beginning with 1954-1955, after the opening of the Volga-Don Canal, did essential changes occur in the fouling: on the bottoms of ships, the barnacles Balanus improvisus and B. eburneus, the bryozoan Electra crustulenta, the polychete Mercierella enigmatica, the hydroid Blackfordia virginica, many algae and mobile organisms encountered in the fouling--the crab Rhithropanopeus harrisi, the mollusk Monodacna colorata, and others--a total of about a score of species penetrated into the Caspian Sea. Thereby, the numbers of the introducents as a rule, considerably exceeds the census of the local species. In various parts of the sea the changes in the fouling occurred at different times. Therefore, we shall analyze each part of the Caspian Sea separately.

I. Fouling in the North Caspian

Here, the greatest influence on the fouling organisms is exerted by the reduced and markedly varying salinity. Its changes, just as the content of organic matter and the quantity of plankton, serving as feed for the fouling organisms, depend on the suspended matter in the Volga. Of great significance is the current which passes along the western shore of the Caspian to the South. It carries the larvae of attached organisms which live in the northern part of the sea to the South. Some new introducents (Balanus improvisus, the crab Rhithriopanopeus) first appeared in the North and then began to spread along the western shore to the South. B. improvisus was first found by Sayonkova (25) in 1955 in the area of Ostrov /Island/ Kulaly and almost simultaneously by Derzhavin (6) at Izberg; Rhithropanopeus was found in 1958 in the North Caspian (21). The abundance of seston creates considerable turbidity in the North Caspian; therefore, the algal fouling does not go deeply in this part of the sea. The ice regularly destroys the encrustations located near the surface of the water. The icy nature of the region, as pointed out by Tarasov (27), is significant for fouling not only because of the fact that the ice tears off the fouling but also because it cleans off the anti-fouling and anti-rust coverings.

We studied the fouling of the North Caspian in 1953, 1958 and 1960 on buoys (Sulakskiy, Nos 20, 40 (or 24), 50, 73, 74, 142), which in every case had stood from April until November-December (Fig 1). The biomass of the encrusting fauna in 1958 increased by almost eight times compared with 1953; in 1960, by five times (Table 1). In both cases the main increase in the biomass was given by the new introducent, Balanus. Changes in the biomass of Dreissena and Mytilaster depended on the salt content of the water. With reduction in the salinity of the water in 1958 (Table 2) the biomass of Dreissena increased; that of Mytilaster decreased. In 1960, the salt content of the water again increased, which again caused an increase in the biomass of Mytilaster and a reduction in the biomass of Dreissena.

As has already been reported (13), introduction of the barnacle /Balanus/ did not reduce the census of any of the encrusting fauna. Conversely, the total biomass of the aborigines increased in both 1958 and 1960, and this indicates that the conditions for them improved with the introduction of the barnacles. The barnacle shells formed numerous shelters for mobile organisms and small mollusks and considerably increased the surface to which sessile organisms can attach themselves by comparison with the relatively smooth initial substratum and make it possible for a larger number

Table 1

Biomass of Encrusting Fauna on the Buoys of the North Caspian, Grams per Square Meter.

(1) Организмы	(2) Годы		
	1953	1958	1960
(3) Водоросли	143	213	192
(4) Дрейссена	354	725	344
(5) Митилястер	164	2	398
(6) Гидроиды	730	1177	1033
(7) Корофииды *	119	156	41
(8) Гаммариды	1	18	—
(9) Балянусы	—	9397	5522
(10) Крабы	—	—	11
(11) Общая биомасса	1510	11689	7540

1. Organisms; 2. Years; 3. Algae; 4. Dreissena; 5. Mytilaster; 6. Hydroids; 7. Corophiids (the Biomass of the Corophiids Is Indicated Each Time Including Their Loricas); 8. Gammarids; 9. Barnacles; 10. Crabs; 11. Total Biomass.

of organisms to attach themselves. We cannot yet explain the reason for the marked reduction in the biomass of corophiids and the disappearance of gammarids in 1960. Perhaps, this is explained by the appearance of crabs in this area, which eat the small crustations.

The fouling on the buoys of the western half of the North Caspian is greater than in its eastern portion (Fig 2). Probably, this is associated with the abundance of food brought in by the Volga. The buoys located to the north in 1958-1960, when B. improvisus became the leading form in the fouling, were less encrusted than the buoys located to the south. Evidently, too low a salt content (less than 6-8 grams per thousand) is unfavorable for barnacles. In 1953, even before introduction of the barnacles into the Caspian, the greatest fouling was observed in the western part of the North Caspian. The highest biomass in this year occurred on buoy No 142 and was created there by Dreissena. In 1958 and 1960, on buoy No 142 and the adjacent buoy No 3, the fouling was not much less than in 1953. On buoys located to the south it was even greater. In this area, because of the considerable fresh water content there were practically no barnacles, and Dreissena was predominant in the fouling. The bryozoan Electra crustulenta appeared on the buoys at Bautino in 1958. In 1960, it was quite abundant on these

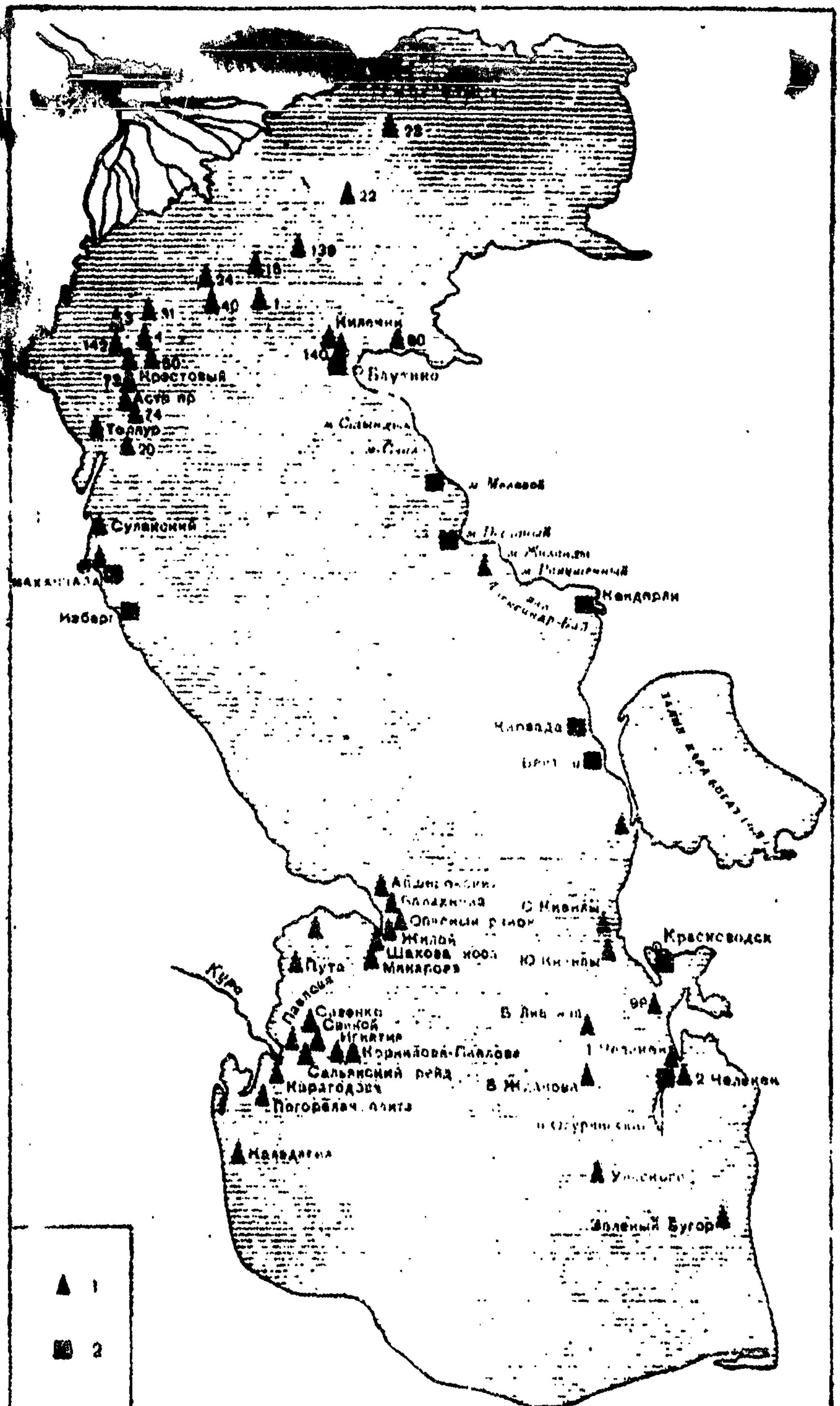

Fig 1. Points at Which Fouling Samples Were Taken.

/Continued on Next Page/

/Fig 1, Continued from Previous Page/. 1. From Buoys; 2. From Rocks and Marlin Spikes.

Table 2

Mean Monthly Salt Content at the Surface of the Water at Ostrov /Island/ Tyuleniy, Grams Per Thousand.

1 Годы	Месяцы 2												Среднегодовая 3
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1953	11,7	10,6	9,3	7,9	7,4	3,9	2,9	5,4	5,5	7,1	4,1	5,3	5,5
1958	6,0	4,7	4,3	3,4	4,7	—	2,9	3,9	3,9	4,7	5,1	6,9	4,7
1960	5,4	4,8	6,5	4,6	3,2	4,0	7,4	6,2	7,0'	3,8	4,8	5,5	5,3

1. Years; 2. Months; 3. Average for the Year.

buoys but had not yet appeared in the other regions of the North Caspian. No essential increase in the biomass of the fouling was observed because of this species; even the converse was the case: where the bryozoan settled first barnacles did not grow.

II.

Fouling on the Western Coast

The water along the western coast is different from the water of the North Caspian in having a higher and more persistent salt content (about 12-13 grams per thousand) and greater transparency. The salinity of the water increases somewhat toward the South. The temperature in the South increases considerably, which has an influence on the growth rate of organisms. The leading forms of fouling along the entire Western coast, aside from the very much contaminated ports, are the same. The fouling of the Middle and South Caspian are different from that of the North Caspian in the fact that while Dreissena is encountered in the North, only Mytilaster participates in the fouling of the coastal waters of the Middle and South Caspian.

Balanus improvisus appeared almost at the same time along the western coast and in the North. In 1956, this species was encountered in abundance along the western shore

(10). B. eburneus was found on the west coast in 1959 in the sheltered and polluted bays of Ostrov Artem (20). Electra, which appeared in the Caspian Sea only in 1958, along the eastern shore (1, 11), was found in 1960 in the area of Makhach-Kala, in the neighborhood of Bakinskaya Bukhta [Bay] and south of it. The crab Rhithropanopeus, first found in 1958, had spread along the entire western shore of the sea by the winter of 1960-61.

Fouling in the Region of Isberg. The most detailed observations were made in the region of Isberg, where the fouling was collected from the poles of an oil stockade and from experimental plates. The introduction of the barnacles had a particularly great influence on the early stages of the succession. In 1951-1955, before introduction of the barnacles, the fouling biomass on the plates which had stood in the sea for four-five months reached approximately one kilogram per square meter. In 1956, when the barnacle appeared, the fouling biomass on these plates was about three kilograms per square meter. In 1957, when the barnacles became numerous, the biomass of them alone occurring on the plates four-five months after they were exposed was six kilograms per square meter; in addition, six kilograms per square meter came from the autochthons, whose number, as has been mentioned above, also considerably increased during these years.

In the fouling which had existed for many years on the poles the effect of the new introducent was most appreciable at the water's edge, where prior to its appearance algae, which do not produce a large biomass, had been predominant but where the poorly attached Mytilaster was washed away by strong waves (12). Barnacles, which can withstand a shearing force from 67 to 74 kilograms each (2), even withstand strong wave impacts. While in 1956 the average barnacle biomass at the water's edge was about 2.5 kilograms per square meter, in 1957 it had increased to almost six kilograms per square meter, and along with this there was also an increase in the biomass of Mytilaster (to 2.6 kilograms per square meter).

On the poles which had stood at Isberg for several years, not only a large barnacle biomass but also a Mytilaster biomass which had increased to almost nine kilograms per square meter were observed. Such a large Mytilaster biomass at the water's edge had never been observed previously.

At a depth of 1.5 meters the barnacle and Mytilaster biomasses in 1958 were equal to 6.8 kilograms per square meter each; even deeper, the barnacle biomass was 4.5 kilograms per square meter; that of Mytilaster, as high as three kilograms per square meter. Here, the biomass of Mytilaster practically did not change after the appearance of barnacles. Both on the plates and on the poles in 1956 there were few barnacles, but in 1958 their number had reached a peak (five kilograms per square meter). It may be supposed that in the future the

number of barnacles will decrease somewhat, as we observed in the North Caspian in 1960.

Fouling in the region of Apsheronskiy Poluostrov /Apsheron Peninsula/. In 1953-1954, 1958-1959, 1960-1961 we collected fouling from buoys at the following banks: Apsheronskiy, Opasnyy, Balakhnina, Makarova Tsuryupa, and Zhiloy, Khanlar Margin, Svaynoye Soorusheniy, Shakhova Kosa Islands. Not all the buoys were examined every year; in addition, the buoys stood in the water for different periods-- from one to two years. However, because every year there were buoys which had stood one, one and a half, and two years, we considered it possible to combine all these data (Table 3), obtaining a picture of the fouling characteristics of the region.

Table 3

Biomass (Grams per Square Meter) of Fouling on Buoys Which Had Stood in the Area of Apsheronskiy Poluostrov one-two years.

1 Организмы	2 Годы 1953—1954	1958—1959	1960—1961	[illegible]	2 Годы 1953—1954	1958—1959	1960—1961
3 Водоросли	612	383	925	Балянусы 8	—	4625	5225
4 Гидроиды	271	—	222	Синдесмия 9	—	—	1
5 Корофииды	33	470	164	Краб 10	—	—	9
6 Митилястер	8154	2074	3738	Электра 11	—	—	66
7 Кардиум	20	—	13	Общая биомасса 12	9091	7552	10392

1. Organisms; 2. Years; 3. Algae; 4. Hydroids; 5. Corophiids; 6. Mytilaster; 7. Cardium; 8. Barnacles; 9. Syndesmia; 10. Crab; 11. Electra; 12. Total Biomass.

In 1953-1954, Mytilaster was predominant in the fouling; the other animals and algae were comparatively sparse. These were algae, hydroids, corophiids and small cardiids. The latter were always encountered among thick colonies of Mytilaster, because Mytilasters held the cardiids, attaching to them with byssus threads.

In 1958-1959, barnacles were predominant in the fouling which had appeared in 1956 (10). The biomass of Mytilaster decreased by four times. In the same year /1958-1959/ there were no hydroids at all but the number of corophiids had increased by many times.

In 1960-1961, the number of barnacles increased and there was a simultaneous increase in the number of specimens of Mytilaster and hydroids and a decrease in the number of

cerripedes by comparison with 1958. In 1960 the new introducents--crab, Electra and even Syndesmia, which, like Cardium, had come into the groups of Mytilaster--played an appreciable role, though less than the forms mentioned above. The total biomass of fouling on the buoys in 1958 decreased somewhat; in 1960 it increased a little compared with 1953. The considerable changes in biomass as had occurred in the North Caspian were not observed here. Probably, this was explained by a marked drop in the Mytilaster biomass in this region, and because one-two-year fouling in which Mytilaster was predominant was taken, even the appearance of a large number of barnacles and other new introducents could not compensate for the reduction in the numbers of Mytilaster.

The Mytilaster biomass on buoys which had stood from one to two years was four-sixteen kilograms per square meter in 1953; on buoys which had stood one-one and a half years, 1.5-5 kilograms per square meter in 1958. However, even with such a marked reduction in the number of Mytilaster its biomass exceeded that of the barnacles. The greatest barnacle biomass was observed on buoys which had stood nine months; then it gradually fell off, whereas the Mytilaster biomass increased.

A number of authors (9, 24, 31) note that the barnacle colonies are gradually replaced by colonies of mollusks. Therefore, it becomes understandable why the fouling had not increased markedly on the buoys which had stood in this region for a long time.

The reduction of the Mytilaster biomass in this region was caused by some kind of hydrological or biological factor, the nature of which could not be determined. We cannot believe that the introduction of barnacles had an influence here, because in this case the Mytilaster biomass would have decreased just as much in the other regions of the sea, but this did not occur. Possibly, the progressively greater pollution of Bakinskaya Bukhta, which is now affecting the waters surrounding the bay also, played a part.

Fouling in the Region of the Baku Archipelago and Zaliv /Gulf/ Kirova. In this region the samples were taken in 1953-1954 and in 1958-1959 from buoys which stood off Svinoy, Kamen' Ignatiya Islands and from the banks of Pogorelaya Plita, Kornilova-Pavlova, Pavlova, Savenko, Karagedova, Sal'yanskiy Reyd, Kuril'skaya Otmel', Kaladagiya. We combined the data for buoys which had stood in this area for about a year (Table 4). In 1958-1959 there was an appreciable reduction in the quantity of Mytilaster by comparison with 1953-1954 but not so great as at the Apsheronskiy Poluostrov. There was also a marked reduction in the biomass of hydroids, which was observed throughout the sea in 1958. However, because of the barnacles the total fouling

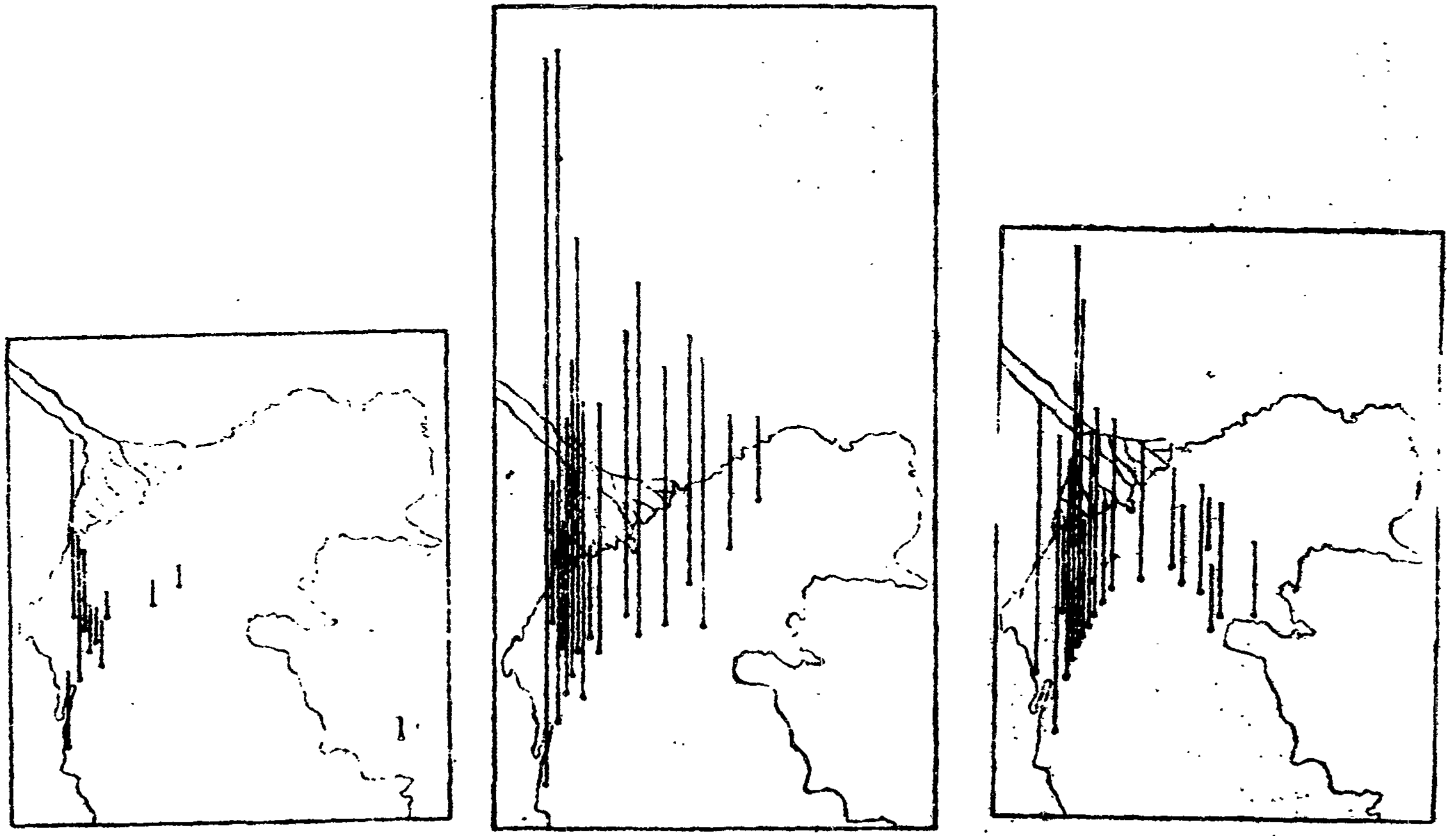

Fig 2. Average Biomass of Fouling on the Buoys in the North Caspian:
A. On Buoys Which Had Stood in the Water from April to November-December 1953;
B. On Buoys Which Had Stood in the Water from April to November-December 1958;
C. On Buoys Which Had Stood in the Water from April to November-December 1960;
1. Length of the Column = One Kilogram per Square Meter.

biomass increased by more than two times. Such an increase is partly explained by the fact that we took annual fouling, where the quantity of barnacles is usually high. Probably, the higher water temperature and lower degree of pollution than in the previous region played a part also. In 1960-61, in this area of the sea it was impossible to take quantitative samples. However, qualitative samples taken from the buoys and samples taken by N. Pavlova and I. A. Sadykhova in the summer of 1961 in Zaliv imeni Kirova permit us to say that the crab and Electra are encountered along the western shore of the Caspian to the border. In addition, on shells of crabs from Zaliv Kirova and on ships from Sal'yanskiy Reyd we found a hydroid, which has not been seen before in the Caspian Sea, classified as Perigonimus medas Kinne by D. V. Naumov. Sadykhova (26) noted a large number of barnacle larvae among the plankton of Zaliv Kirova.

Fouling in Bakinskaya Bukhta. In Bakinskaya Bukhta the fouling is different from the other regions of the Caspian, because here the greatest influence is exerted by the industrial and domestic pollution (12, 22). With respect to its degree of pollution Bakinskaya Bukhta can be divided into three areas: the first area, which is adjacent to the part of the city where, aside from domestic pollution, chemical wastes of numerous enterprises enter the water; in this area there is a complete absence of gross fouling. In the second area, which borders the first area near the city and comes close to the shores only where the first area ends, domestic pollution and pollution with petroleum products predominates, and here the main fouling consists of the bryozoans Bowerbankia umbricata caspia, Victorella pavida as well as the blue-green and diatomaceous algae. The third area occupies the middle portion of the bay and of the strait leading into it. The water here is purer; however, there is much organic matter and petroleum products here. The leading forms of fouling are Mytilaster, Balanus improvisus and the bryozoan Bowerbankia. The first two species are in a depressed state. The barnacle shells are thin-walled and fragile. In the colony there are a large number (sometimes more than half) of dead individuals.

Changes in the fouling which occurred in the Caspian Sea did not at all affect the first and second areas of Bakinskaya Bukhta. In the first area, as before, fouling is absent; in the second area it is represented only by bryozoans and some algae. This is useful for ships based in Bakinskaya Bukhta, because those ships which are anchored at the shores come into the first or second area, and here they are not encrusted at all or else they are covered with a film of bryozoans, which produce a comparatively small biomass, not more than 0.8 kilogram per square meter. Large ships which stand at anchor can be encrusted with barnacles and

Mytilaster, because they are in the third area, where as early as 1958 barnacles were encountered in large numbers. However, the settlement and survival of barnacles and Mytilaster in this part of the bay depend on the winds and the currents which they produce. In the presence of long-lasting driving winds the water becomes very much polluted, and the barnacles and Mytilaster die. Therefore, even in this, the cleanest part of the bay, conditions for the development of fouling are less favorable than in the other regions of the Caspian Sea. New introducents, aside from B. improvisus, have not yet been noted in Bakinskaya Bukhta.

Table 4

Biomass of Fouling on the Buoys Standing in the Region of the Baku Archipelago About a Year, Grams per Square Meter.

1 Группы организмов	2 Годы		1 Группы организмов	2 Годы	
	1953—1954	1958—1959		1953—1954	1958—1959
3 Водоросли	275	409	Гаммариды 7	—	6
4 Гидроиды	944	41	Митиластер 8	4048	2195
5 Корофииды	—	386	Балянусы 9	—	8924
6 Нереис	—	10	Общая биомасса 10	5267	11991

1. Groups of Organisms; 2. Years; 3. Algae; 4. Hydroids; 5. Corophiids; 6. Nereis; 7. Gammarids; 8. Mytilaster; 9. Barnacles; 10. Total Biomass.

At the entrances to Bakinskaya Bukhta, on the buoys standing off Ostrov Nargina, in some years unusually large fouling was observed. In 1954, on a buoy here, which had stood for one and a half to two years, the average biomass was about 19 kilograms per square meter and the largest biomass reached 20 kilograms per square meter. The stimulating effect of domestic sewage on certain organisms (Balanus improvisus, Rhithropanopeus harrisi and Nereis succinea) has been shown by Filice (29). Substances harmful to the organisms are present here in such concentration that they cannot kill or check the following, and the large quantity of organic impurities and, probably, the plankton make it possible for a large number of animals to develop. However, in some years the biomass on the buoys in this region was considerably less. For example, in 1958 the average fouling biomass on the Ostrov Nargina buoy after it had been in the water for nine months was five kilograms per square meter, whereby the

majority of barnacles had died. Probably, the currents in this year had come from polluted places in the bay to the buoy, and the barnacles could not stand such great pollution.

III. Fouling Along the Eastern Shore

In its open parts the Eastern shore is distinguished from the Western by greater clarity of the water, a smaller content of organic matter in the water, and frequent driving winds in the summer. Because of the clarity of the water the algal zone goes much deeper here and, correspondingly, the fauna begin to predominate at a greater depth. A smaller quantity of organic matter and plankton causes some impoverishment of the benthos. The driving winds also contribute little to the development of fouling, carrying off the larvae of encrusting fauna into the open sea. The main current goes from the North Caspian along the Western shore to the South and then goes northward along the Eastern shore. Therefore, the encrusting fauna introduced into the North Caspian first spread along the Western shore and then along the Eastern. This is how it was with the barnacles. The same thing occurred with the crab, which for two years (from 1958 to 1960) settled and spread along the entire Western shore and only in the summer of 1960 did it first appear on the Eastern shore. However, the conditions along the entire Eastern shore are inhomogeneous; temperature differences are particularly great in the northern and southern parts of the East coast. Krasnovodskiy Zaliv is distinguished particularly in its temperature conditions, salinity and other factors.

Fouling in the Region of Zaliv Aleksandr Bay. This region is far from the sea transport lanes. True, sometimes fishing vessels come here and bring in new fouling organisms. However, in general, because of its remote location, introducents appeared here later than in the other areas. Thus, in 1956, in the gulf and in its environs barnacles had not yet appeared (13). In 1958 there were few of them, but by 1960 their biomass had increased by three-four times (Table 5). The other introducents, crab, Electra, Mercierella) had not yet appeared in the area between Kenderli and Bautino in 1960. If we consider the general rate of dispersal, these introducents may be expected here after one-two years.

The fouling biomass in Zaliv Aleksandr Bay is greater than in the Bautino region, which is possibly explained by the fact that the Gulf [Zaliv] is somewhat sheltered from the wind and the water here is warmer.

Fouling in the Region of Kenderli and in the Environs of Kara-Bogaz-Gol. This area is warmer, although in the summer the abysmal cold waters sometimes come to the surface.

Table 5

Biomass of Fouling Organisms on a Buoy in Zaliv Aleksandr Bay After Seven Months, Grams per Square Centimeter.

(1) Группы организмов	(2) Годы		
	1953	1958	1960
(3) Водоросли	504	318	500
(4) Митилястер	2	—	3
(5) Корофииды	200	149	407
(6) Гаммариды	—	4	13
(7) Гидроиды	196	182	280
(8) Балянусы	—	862	3084
(9) Общая биомасса	902	1513	4343

1. Groups of Organisms; 2. Years; 3. Algae; 4. Mytilaster; 5. Corophiids; 6. Gammarids; 7. Hydroids; 8. Barnacles; 9. Total Biomass.

Therefore, the fouling biomass here is considerably greater (Table 6) than in the more northerly regions of the East coast. No Electra, Mercierella or crabs were encountered here either. At the entrance to Krasnovodskiy Zaliv, where it is warmer, the fouling biomass is considerably more abundant than at Kara-Bogaz-Gol.

Fouling in the Area of Ostrov Ogurchinskiy. In this region a very large amount of fouling is always observed because of the high water temperature. We do not have any comparative data for this region for different years. In 1954, samples were taken from a buoy which had stood at Banka Livanov for seven months (Table 7). The biomass of the fouling on this buoy (7.5 kilograms per square meter) was more than four times greater than on the buoys in the North Caspian before the introduction of the barnacles. On buoys which had stood 17-18 months and had been taken out of the water in 1961, the biomass of the fouling was 11 kilograms per square meter, which is not so much if we compare it with the biomass on buoys standing at the entrance to Krasnovodskiy Zaliv or in the straits leading to Kara-Bogaz-Gol. Possibly, the buoys stood far from the shore and fewer larvae settled on them.

Table 6

Biomass of Fouling Organisms (Grams per Square Meter) on the Buoys Which Had Stool at Kianly for Seven Months, at the Entrance to Krasnovodskiy Zaliv for Seventeen Months, and in Kara-Bogaz-Gol, for Twenty Months.

(1) Группы организмов	(2) У Кианлы	(3) У [illegible] в Красноводский залив	(4) У [illegible] в Кара-Богаз-Гол	(1) Группы организмов	(2) У Кианлы	(3) У [illegible] в Красноводский залив	(4) У [illegible] в Кара-Богаз-Гол
(5) Водоросли	995	1170	938	Баланусы (10)	5887	11361	10120
(6) Митилястер	1579	8820	3498	Гидроиды (11)	—	572	440
(7) Корофииды	509	—	838	Кардиды (12)	—	—	18
(8) Гаммариды	1	—	—	Креветки (13)	—	480	—
(9) Нереис	10	—	—	Общая биомасса (14)	[illegible]	22412	15850

1. Groups of Organisms; 2. At Kianly; 3. At the Entrance to Krasnovodskiy Zaliv; 4. At the Entrance to Kara-Bogaz-Gol; 5. Algae; 6. Mytilaster; 7. Corophiids; 8. Gammarids; 9. Nereis; 10. Barnacles; 11. Hydroids; 12. Cardiids; 13. Prawns; 14. Total Biomass.

Table 7

Biomass of Fouling on Buoys to the South of Krasnovodskiy Zaliv, Grams per Square Meter.

(1) Группа организмов	(2) Буй на банке Ливанова стоял 7 месяцев в 1954 г.	(3) 7 [illegible] стояли 17—18 месяцев с 1959 по 1961 г.
(4) Водоросли	880	1407
(5) Гидроиды	675	149
(6) Митилястер	5978	4915
(7) Корофииды	—	197
(8) Гаммариды	—	17
(9) Баланусы	—	5344
(10) Общая биомасса	7533	11129

1. Groups of Organisms; 2. Buoy at Banka Livanov, Stood for Seven Months in 1954; 3. Seven Buoys Which Stood for 17-18 Months, from 1959 to 1961; 4. Algae; 5. Hydroids; 6. Mytilaster; 7. Corophiids; 8. Gammarids; 9. Barnacles; 10. Total Biomass.

Fouling in Krasnovodskiy Zaliv. The gulf heats up well in the summer, but in the winter the temperature is quite low. The salt content of the water is somewhat higher than in the sea (approximately 14 grams per thousand) and, the main thing, the gulf is sheltered to such a degree that the larvae of organisms coming into it on the bottoms of ships remain here and are not carried out into the open sea. After settling in Krasnovodskiy Zaliv, such organisms subsequently attach themselves to the bottoms of ships and are carried all over the sea. It is very probable that this occurred with B. eburneus, which was first found here in 1956 (10). Electra was also first found in Krasnovodsk (11). From here it apparently was carried to Bautino on the bottoms of ships and then to the areas of Baku, Makhach-Kala, Lenkoran' and other ports in the Middle and South Caspian. We first found Mercierella in the winter of 1961 on the bottoms of ships traveling between Baku and Krasnovodsk; in the summer of 1961 it was encountered in Krasnovodskiy Zaliv in mass numbers. In the autumn of 1961, in the gulf and in its environs, we found an alga new for the Caspian, classified by L. D. Zinova as Monostroma latissimum (Kuetz) Wittr. B. improvisus was not found in Krasnovodsk first, but it must be supposed that in 1956 it was encountered in the bay, although we did not find it in the fouling on hawsers. This species is encountered in Krasnovodskiy Zaliv only in the middle part of the bay and at the exit from the bay, which we did not investigate in 1956 and 1958. However, probably B. improvisus was already here in 1956 and, perhaps, in 1955 also, because in 1956 it was encountered in the environs of the bay. According to the verbal report of N. N. Kondakov, in the summer of 1961 the medusa Blackfordia virginica, which had settled in the Caspian Sea several years before (17, 18) was encountered in Krasnovodskiy Zaliv in mass numbers. The polyps of this medusa had not yet been encountered in the fouling.

With respect to the composition of its fouling in 1961 Krasnovodskiy Zaliv can be divided roughly into two areas. The first area, the coastal strip in the region of the city, is very much polluted with domestic wastes from the city and from ships. Here, the fouling on the mooring posts is extraordinarily considerable, of the order of 30–40 kilograms per square meter. The leading forms of fouling are Mytilaster, B. eburneus, Bowerbankia and Mercierella. The second area consists of the pure waters of Krasnovodskiy Zaliv; the leading forms of fouling here are Mytilaster, B. improvisus, Coldylophora caspia and corophiids. The average fouling biomass is somewhat less, about 20 kilograms per square meter. In sea water pipes, which really belong to the first area, organisms of the second area are, as a matter of fact, encountered in large numbers, namely, Coldylophora and B.

improvisus.

This occurs because conditions in the fast current of water within the pipes are more like those in the pure waters of the gulf than in the stagnant polluted waters near the shore.

The growth rate of fouling organisms in Krasnovodskiy Zaliv is high and animals here reach a large size, such as we have not encountered in other regions of the Caspian Sea. A considerable number of the Mytilaster on the mooring posts at the port reached lengths of 20-25 millimeters and even 30 millimeters, and B. eburneus had a diameter of its base of up to 28 millimeters and a height of 25-28 millimeters.

Conclusion

The introduction of new encrusting organisms not only changed the fouling in the Caspian Sea but also had an influence on the life of the entire water body. The basis of the fouling is constituted by attached organisms. They make it possible for moving organisms to exist among them; the latter find shelter there and, in the majority of cases, food also. So far, moving forms specific of fouling are unknown. The number of mobile organisms in the fouling usually considerably exceedstheir number encountered on other substrata, although exact calculations have not yet been made for the Caspian. There is a constant circulation between moving fouling organisms and benthos. Certain benthos-eating fish feed on the moving and on many sessile organisms.

The fouling is also connected with plankton. Plankton serves as food for many fouling organisms; Dreissena, Mytilaster, barnacles, hydroids and bryozoans partially or completely feed on plankton. On the other hand, the fouling organisms supplement the plankton with their own larvae. In recent years, in the coastal regions of the Caspian, barnacle larvae constitute up to 60 percent of the plankton in the summer (26). Evidently, they constitute a considerable fraction of the ration of plankton-eating fish. In their turn, the barnacle larvae can eat the larvae of fish (7). The filtering fouling organisms exert a considerable influence on the suspension present in the water, not only utilizing it as food but also precipitating it to the bottom (5). In the future, the introduction of a number of other animals from the Black Sea and Sea of Azov into the Caspian Sea may be expected. The appearance of new species of hydroids, bryozoans, polychetes and some crustaceans should not exert much effect on the fouling existing at the present time. The role of such organisms as crabs, Chthamalus stellatus, C. depressus, and the mollusk Rapana. However, the greatest influence can be exerted by mussels and teredinids if they are able to pene-

trate into the Caspian Sea. Mussels will increase the fouling biomass, particularly the perennial biomass, by 2-3 times, and during the first few years after introduction when there is an outburst of the new organism, the fouling may be increased even more.

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